the medulated fibre which preserves its sheath up to the point where its large nucleus appears. The latter occupies the lumen and is quite conspicuous, while ectad of it the fibre is reduced to a sensory rod with small rigid styles or cilia at the apex. Such termini are quite generally distributed over the skin of the head and take the place of the buds found in other types. The double staining is exceptionally good, and teased preparations produced by pressure on the cover glass permit the isolation of the termini and their study under immersion lenses. It seems probable that the differences of opinion which still prevail in this matter are the result of the partial results of the different methods, and that the truth will be reached by an intelligent employment of the data from them all. In conclusion the writer desires to acknowldgee the substantial assistance rendered, especially in the laboratory manipulation on which this paper is based, by his friend Mr. G. E. Coghill, in collaboration with whom a more detailed report of the histological processes and results may be expected in the *Journal of Comparative Neurology* at no distant date.

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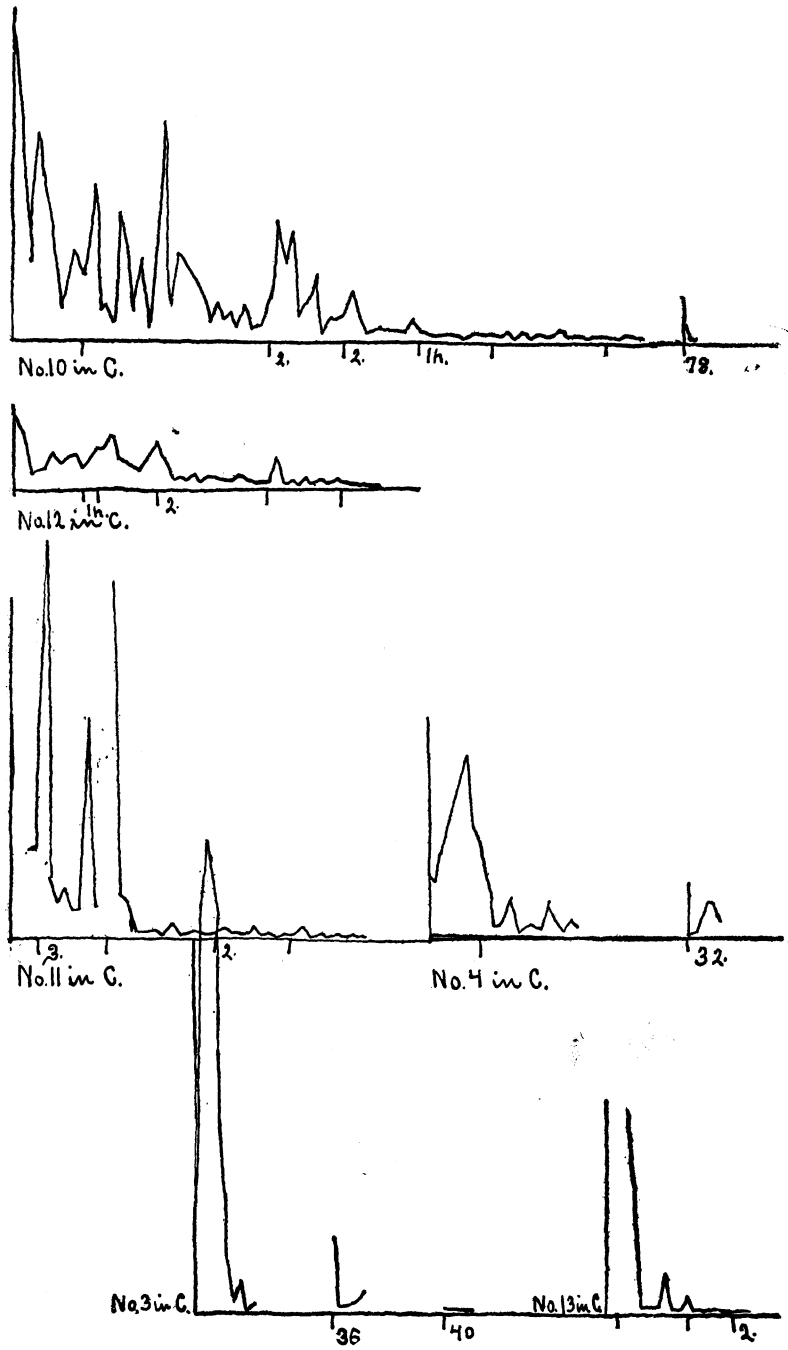
## *SOME EXPERIMENTS ON ANIMAL INTELLIGENCE.*

The results of a recent investigation on animal intelligence, the details of which are about to be published,* seem to be of sufficient general interest to deserve an independent statement here. The experiments were upon the intelligent acts and habits of a considerable number of dogs, cats and chicks. The method was to put the animals when hungry in enclosures from which they could escape (and so obtain food) by operating some simple mechanism, *e. g.*, by turning a wooden button that held the door, pulling a loop attached to the bolt, or pressing down a lever. Thus one readily sees what sort of things the animals can learn to do and just how they learn to do them. Not only were the actions of the animals in effecting escape observed, but also in every case an accurate record was kept of the times taken to escape in the successive trials. The first time that a cat is put into such an enclosure, some minutes generally elapse before its instinctive struggles hit upon the proper movement, while after enough trials it will make the right movement immediately upon being put in the box. The time records show exactly the method and rate of progress from the former to the latter condition of affairs. A graphic representation of the history of six kittens that learned to get out of a box $20 \times 15 \times 12$ inches, the door of which opened when a wooden button $3\frac{1}{2}$ inches long, $\frac{7}{8}$ inch wide, was turned, is found in the curves in Figure 1. These curves are formed by joining the tops of perpendiculars erected along the abscissa at intervals of 1 mm. Each perpendicular represents one trial in the box; its height represents the time taken by the animal to escape, every 1 mm. equalling 10 seconds. A break in the curve means that in the trials it stands for, the animal failed in ten minutes to escape. Short perpendiculars below the abscissa mark intervals of twenty-four hours between trials. Longer intervals are designated by figures for the number of days or hours. The small curves at the right of the main ones are, as the figures beneath them show, records of the skill of the animal after a very long interval without practice. This process of associating a certain act with a certain situation is the type of all the intelligent performances of animals, and by thus recording the progress of a lot of animals, each in forming a lot of each kind of associa-

* Animal Intelligence; An Experimental Study of the Associative Processes in Animals; *Psychological Review*, Supplement No. 8.


No.10 in C.
2.
2.
1h.
78.
No.12 in C.
1h.
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No.11 in C.
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32.
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36
40
No.13 in C.
2.

FIG. 1.

tion, one gets a quantitative estimate of what animals can learn and how they learn it.

What happens in all these cases is this: The animal on being put into the box, and so confronted with the situation 'confinement with food outside,' bursts forth into the instinctive activities which have in the course of nature been connected with such a situation. It tries to squeeze through any openings, claws and bites at the walls confining it, puts its paws through and claws at things outside trying to pull itself out. It may rush around, doing all this with extraordinary vehemence and persistence. If these impulsive activities fail to include any movement which succeeds in opening the door, the animal finally stops them and remains quietly in the box. If in their course the animal does accidentally work the mechanism (claw the button round, for instance), and thus win freedom and food, the resulting pleasure will stamp in the act, and when again put in the box the animal will be likely to do it sooner. This continues; all the squeezings and bitings and clawings which do not hit the vital point of the mechanism, and so do not result in any pleasure, get stamped out, while the particular impulse, which made the sucessful clawing or biting, gets stamped in, until finally it alone is connected with the sense-impression of the box's interior, and it is done at once when the animal is shut in. The starting point for the formation of any association is the fund of instinctive reactions. Whether or not in any case the necessary act will be learned depends on the possibility that in the course of these reactions the animal will accidentally perform it. The progress from accidental performance to regular, immediate, habitual performance depends on the inhibiting power of effort without pleasure and the strengthening by pleasure of any impulse that leads to it.

Although it was of the utmost importance to them to get out of the various boxes and was, therefore, certain that they would use to the full all their mental powers, none of the animals gave any sign of the possession of powers of inference, comparison or generalization. Moreover, certain of the experiments seem to take the ground from beneath the feet of those who credit reason to animals. For it was found that acts (*e. g.*, opening doors by depressing thumb-latches and turning buttons) which these theorizers have declared incapable of performance by mere accident *certainly can be so done.* It is, therefore, unnecessary to invoke reasoning to account for these and similar successes with mechanical contrivances, and the argument based on them falls to the ground. Moreover, besides destroying the value of the evidence which has been offered for the presence of reason in animals, the time-records give us positive evidence that the subjects of these experiments could not reason. For the slopes of the curves are *gradual.* Surely if a cat made the movement from an inference that it would open the door, it ought, when again put in, to make the movement *immediately.* If its first success was due to an inference, all trials after the first should take a minimum time. And if there were any slightest rudiment of a reasoning faculty, even if no real power of inference, the cat ought at least sometime, in the course of ten or twenty successful trials, to realize that turning that button means getting out, and thenceforth make the movement from a decision, not a mere impulse. There ought, that is, to be a sudden change from the long, irregular times of impulsive activity to a regular minimum time. The change is as a fact very gradual.

Finally, experiments made in another connection show that these animals could not learn to perform even the simplest acts by seeing another do them or by being put

through them by the experimenter. They were thus unable to infer that since another by pulling a string obtained fish, they might, or that since fish were gained when I pushed round a bar with their paws it would be gained if they pushed it round themselves.

Experiments were made on imitation by giving the animals a chance to see one of their fellows escape by clawing down a string stretched across the box, and then putting them in the same box alone. It was found that, no matter how many times they saw the act done, they could not thereby learn anything which their own impulsive activity had failed to teach them, and did not learn any more quickly what they would have sooner or later learned by themselves. One important consequence of these results is the resulting differentiation of the Primates from the other orders of mammals. If the Primates do imitate and the rest do not, we have located a definite step in the evolution of mind and given a new meaning to the line of human ancestry. I do not, however, hold that these results eliminate the possibility of an incipient faculty of imitation among mammals in general. They do deny the advisability of presupposing it without proof, and emphatically deny its presence in anything equivalent to the human form. Finally many actions which seem due to imitation may be modifications of some single instinct, such as that of following.

Perhaps the most valuable of the experiments were those which differentiate the process of association in animals from the ordinary 'association by contiguity' of human psychology. A man, if in a room from which he wishes to get out, may think of being outside, think of how he once opened the door, and accordingly go turn the knob and pull the door open. The *thought* of opening the door is sufficient to arouse the act of opening the door, and in most human association-series the *thoughts* are the essential and sufficient factors. It has been supposed that the same held true of animals, that if the thought *of doing* a thing were present an impulse *to do* it would be readily supplied from a general stock. Such is not the case. *None of these animals could form an association leading to an act unless there was included in the association an impulse of its own which led to the act.* Thus cats who had been induced to crawl into a box as the first element in a pleasurable association-series soon acquired the habit of crawling in of their own accord, while cats who had been *dropped in* did not. In the second case the *idea of being in* would be present as strongly as in the first, but the particular *impulse to go in* was not. So also cats who failed of themselves to learn certain acts could not be taught to do them by being put through them, while cats who were thus put through acts which accident would of itself alone have taught them, learned them no more quickly and often made the movement in a way quite different from that which they were shown. Their associations are not primarily associations of ideas with ideas, but associations of sense-impressions and ideas *with impulses to acts, muscular innervations.* The impulse, the innervation, is the essential.

This does not mean that the animals can have no representations or images at all. Another set of experiments show that they probably can. It means that they have no stock of free-floating impulses which can be called on at will; that the elements of their associations occur chiefly just in their particular connections; that their ideational life consists not of a multitude of separate ideas, but of a number of specific connections between ideas and impulses.

Having thus denied that animal association is homologous with human association, as the latter is ordinarily conceived, we find the true homologue of animal associa-

tion in the mental process involved when a man learns to play tennis or billiards or to swim. Both contain sense-impressions, impulses, acts, and possibly representations. Both are learned gradually. Such human associations cannot be formed by imitation or by being put through the movement. Nor do its elements have any independent existence in a life of free ideas apart from their place in the associations. No tennis player's stream of thought is filled with representations of the tens of thousands of sights he has seen or movements he has made on the tennis-court, though his whole attention was on them at the time.

The great step in the evolution of human intellection is then not a jump to reason through language, but a change from a consciousness which equals a lot of specific connections to a consciousness which includes a multitude of free ideas. This is the prerequisite of all the human advance. Once get free ideas in abundance, and comparison, feelings of transition or relation, abstractions and 'meanings' of all sorts may emerge. In this respect, as in imitation, the monkeys bear the marks of their relationship.

Besides the experiments resulting in this new analysis of the mental processes of animals, others were made to discover the delicacy, complexity, number and permanence of their associations. It was found that naturally they discriminate very little, that what they react to is a vague, unanalyzed total situation. Thus, cats that had learned to climb up the front of a cage on hearing the words, 'I must feed those cats,' would climb up just as readily if you said, 'What time is it?' or any short sentence. By associating only the right reaction with pleasure, however, you can render the association delicate to any degree consistent with their sense powers. For instance, a cat was taken that was just beginning to form the association between the words, 'I must feed those cats,' and the act of climbing up the front of the cage (after she climbed up she was given a bit of fish). She was now given a lot of trials, some as just described, some with the signal changed to, 'I will not feed them.' At these trials she got no fish. The purpose was to see how many trials would be required before she would learn always to climb up at the "I must feed" and always stay down at the "I will not." The two sorts of trials were mixed indiscriminately. 60 of the "I must feed"'s were, in addition to its previous training, enough to make the proper reaction to it inevitable. 380 of the 'I will not''s were required before perfect discrimination between it and the former signal was attained.

It was found that complex associations (such, *e.g.*, as the way to escape from a box where the door fell open only after a platform had been pushed down, a string clawed and a bar turned around) were very slowly formed and never really formed at all. That is, the animals did not get so that they went through the several acts in a regular order and without repeating uselessly one element. In respect to delicacy and complexity, then, we see a tremendous difference between association in animals and association in man.

Equally great is the difference in number. A practised billiard player has more associations due to just this one pastime than a dog has for his whole life's activity. The increase in the number of associations is a sign, and very likely a cause, of the advance to a life of free ideas. Yet, small as it is, in comparison with our own, the number of associations which an animal may acquire is probably much larger than previous writers have fancied.

A great many experiments were made on the permanence of associations after from 10 to 70 days. Samples of the results will

be found in the figure given. What an animal once acquires is long in being lost, and this power of retention thus renders the power of acquisition a big factor in the struggle for existence. But these experiments give better information than this quantitative estimate of the value of past experience, for they demonstrate conclusively that the animals have no real memory. The cat or dog that is put into a box from which he has escaped thirty or forty times, after an interval of fifty days without any experience with it, will escape quicker than he did in his first experience and will reach a perfect mastery of the association in much fewer trials than he did before, but he will reach it *gradually*. If he had true memory he would, when put in the box after the interval, after a while think, "Oh, yes! pulling this string let me out," and thenceforth would pull the string *as soon as dropped in the box*. In the case of genuine memory you either know a thing and do it or forget it utterly and fail to do it at all. So with a man recalling the combination to a safe, for instance. But the memory of the animal is only that of a billiard player who hasn't played for a long interval and who gradually recovers his skill. No billiard player keeps thinking, "Two years ago I hit a ball placed like this in such and such a way." And the cat or dog does not think, "When I was in this box before, I got out by pulling that string." Not only the gradual recovery of skill, but also the actions of the animal show this. In case of an association only partially permanent the animal claws around the vital spot, or claws feebly and intermittently, or varies its attacks on the loop or what not, by instinctive bitings and squeezings. Memory in animals is permanence of associations, not conscious realization that a certain event or sequence occurred in the past.

So much for some of the experiments and what theoretical consequences they seem directly to involve. The general view which the entire investigation has forced upon me is that animals do not think *about* things at all, that consciousness is for them always consciousness in its first intention, 'pure experience,' as Lloyd Morgan says. They feel all their sense-impressions as we feel the sky and water and movements of our body when swimming. They see the thumb-latch as the ball-player sees the ball speeding toward him. They depress the thumb-piece, not because they think about the act, but just because they feel like doing so. And so their mental life never gets beyond the limits of the least noticeable sort of human intellection. Conception, inference, judgment, memory, self-consciousness, social consciousness, imagination, association and perception, in the common acceptation of the terms, are all absent from the animal mind. Animal intellection is made up of a lot of specific connections, whose elements are restricted to them, and which subserve practical ends *directly*, and is homologous with the intellection involved in such human associations as regulate the conduct of a man playing tennis. The fundamental phenomenon which I find presented in animal consciousness is one which can harden into inherited connections and reflexes, on the one hand, and thus connect naturally with a host of the phenomena of natural life; on the other hand, it emphasizes the fact that our mental life has grown up as a mediation between stimulus and reaction. The old view of human consciousness is that it is built up out of elementary sensations, that very minute bits of consciousness come first and gradually get built up into the complex web. It looks for the beginnings of consciousness to *little* feelings. This our view abolishes, and declares that the progress is not from little and simple to big and complicated, but from direct connections to indirect connections in

which a stock of isolated elements plays a part; is from 'pure experience' or undifferentiated feelings to discrimination, on the one hand, to generalizations, abstractions, on the other. If, as seems probable, the Primates display a vast increase of associations, and a stock of free-swimming ideas, our view gives to the line of descent a meaning which it never could have so long as the question was the vague one of more or less 'intelligence.' It will, I hope, when supported by an investigation of the mental life of the Primates and of the period in child life when these directly practical associations become overgrown by a rapid luxuriance of free ideas, show us the real history of the origin of human faculty.

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## *THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.*

The American Society of Mechanical Engineers held their spring meeting at Niagara Falls, May 31st to June 3d, inclusive. The reception was initiated by Mayor Hastings in an interesting and cordial address, and by Mr. Coleman Sellers, and Mr. W. A. Brackenridge, who described with lantern-illustrations the work of the Cataract Construction Company. In addition to Society business, the time was given to visits to points of professional interest, at Niagara and at Buffalo and adjacent towns, and, later, at Dunkirk and at Toronto.

Some very important papers were read, Mr. Barrus made a 'Plea for a Standard Method of Conducting Engine Tests'; intending particularly tests of mill-engines; the Society having already, through special committees, established precise methods of engine trial for steam pumping engines and locomotives, and of steam-boilers, which have been accepted as models, almost universally. A standard is now proposed that shall be general and cover the whole field. Mr. Bryan Donkin, an English member of the association, proposes an extension of these systems into other countries. The American Society having led the way in instituting such formal programs, steps should be now taken to secure general adoption throughout the world.

Mr. James See presented a very concise discussion of the principal points to be considered in patenting new devices. Mr. W. H. Bryan discussed 'Relations Between the Purchaser, the Engineer and the Manufacturer,' a phase of economics which is attracting much attention among members of the engineering profession. Mr. G. A. Lowry gave an interesting outline of the development of the industry of ginning and baling cotton, and of the inventions which have brought about its remarkable progress. Messrs. Woolson, Baker, Norton, Cole, Johnson and others discussed the construction, setting and details of steam-boiler practice. Mr. Benjamin detailed results of investigation of the strength of cast-iron cylinders, and Professor Carpenter reported the outcome of the extensive Sibley College researches on the properties of the aluminum alloys, with the various other useful metals and experiments upon the value of a remarkable new seamless tube. Dr. Thurston illustrated a variety of novel 'Graphic Diagrams and Glyptic Models,' employed for representation of the laws of variation of strength of materials of engineering and the economics of the steam engine, mainly of his own devising for use in his researches in these departments.

R. H. Thurston.

## *BOTANICAL NOTES.*

### BOTANY AND AGRICULTURE.

In the Proceedings of the Eighteenth Annual Meeting of the Society for the Pro-